

Comparative investigations of FS welding and Pulsed TIG welding processes of 5083 Aluminum Alloys

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Abstract—In this study, AA5083 aluminum alloy plate of thickness 4mm have been welded by conventional fusion welding process Pulsed Current tungsten inert gas (PCTIG) welding and friction stir welding (FSW) process. The welding process was performed with different process parameters and the joints has been investigated to find their microhardness properties, SEM Images (Scanning Electron Microscope) and Chemical Analysis properties. Vickers hardness tester was used to characterize the hardness of the weld area for both the welding process. Then Scanning Electron microscope is used to analyses the size and shapes of the grains at weld zone and heat affected zone. Taking into consideration the process conditions and requirements, FSW and TIG processes Next test is chemical analysis test on Edax Energy dissipate machine and compared with each other to understand the advantages and disadvantages of the welding processes. Microstructural examination reveals that smaller grain sizes are obtained in the weld centre of FS welded specimens due to recrystallization, where as grain growth has been observed in TIG welded Specimen due to severe heat input. The Vickers hardness test results show that among the two welding methods employed, FSW has yielded the best mechanical properties and found that evaporation of magnesium is more in Pulsed TIG welding compared with FSW process.

Keywords—AA 5083 plates, Micro hardness Properties, Sem Images, Chemical analysis, straight cylindrical pin, Butt Joint.

I. INTRODUCTION

Tig welding is an arc welding process that uses a non – consumable tungsten electrode to produce the weld. The weld area is protected from atmosphere by an inert shielding gas (argon or helium) and a filler metal is normally used. The power is supplied from the power source (rectifier), through a hand piece or welding torch and is delivered to a tungsten electrode which is fitted

into the hand piece. An electric arc is then created between the tungsten electrode and the work piece using a constant current welding power supply that produces energy and conducted across the arc through a column of highly ionized gas and metal vapors. The tungsten electrode and the welding zone are protected from the surrounding air by inert gas.. The welding came into existence from “Bronze Age” about 2000 years ago. But Egyptian people learned to weld iron pieces together during Iron Age. TIG Welding is preferred only for aluminium alloys because it starts to spread out from weld pool during the welding operation in other processes. TIG welding was demonstrated first by Russell Meredith in 1930 during Second World War for welding aluminum and magnesium in aircraft industry. Tig welding with Pulsating current has been known for many years. The welding current weaves periodically between a high (pulse current) and low (basic current) values. In the basic current phase, the low temperature causes a decrease in the volume of the molten pool. The welding has applications in manufacturing field such as ships, boats, cyclic, automotive industry, aircraft industry and pipelines. The weld quality was strongly characterized by weld bead geometry because the weld pool geometry plays an important role in determining mechanical properties of weld. Maximum quality can be achieved with control of welding parameters and material and material used must be cleaned. The heat affected zone influenced with the increment of heat input due to increased welding current. The width of heat affected zone increases due to low heat input. The weld bead geometry of weld repaired aluminium alloy was similar as cast aluminium alloy in appearance but different in micro-structure.

FSW of aluminium alloys has been used in many fields like automotive, aircraft, ship building, railway, defence industries,. The rapid development of FSW in aluminium alloys and its successful implementation into commercial

applications has motivated its application to more non-ferrous materials and other metals. In FSW as a basis a non-consumable H13 tool with a special designed pin and a shoulder is made to plunged in the abutting edges of the plates to be joined to a preset depth and moved along the weld joint. Heat is generated through the frictional contact between the rotating tool shoulder, and abutting material surface. The process is also suitable for automation. The weld produced is of finer microstructure and superior in characteristics to that parent metal. FSW finds application in shipbuilding, aerospace, railway, electrical and automotive industry. The limitations of FSW are reduced by intensive research and development. Its cost effectiveness and ability to weld dissimilar metals makes it a commonly used welding process in recent times. Friction Stir Welding (FSW) is a solid state welding process first discovered and patented by the Welding Institute of Cambridge U.K. in 1991 [1-2]. FSW technique is attractive for joining high strength aluminium alloys since there is far lower heat input during the process compared with conventional welding processes such as TIG, MIG[3-4], which include being a single step process, use of simple and inexpensive tool, less time consuming, no finishing process requirement, less processing time, use of existing and readily available machine tool technology, suitability to automation, flexibility to robot use, being energy efficient and environmental friendly [5]. This process is being used in wide variety of applications in the automotive, aerospace, ship building, and railroad industries [6]. In FSW the interaction of a non-consumable and rotating tool with the work pieces being welded, creates a welded joint through frictional heating and plastic deformation at temperatures below the melting temperature of the alloys being joined. Based on friction heating at the contacting surfaces of two sheets to be joined, a special tool with a properly designed rotating probe travels down the length of contacting metal plates, producing a highly plastically deformed zone through the associated stirring action [7]. The probe is typically slightly shorter than the thickness of the work piece and its diameter is typically slight larger than the thickness of the work pieces [8]. Interesting benefits of FSW compared to fusion process es are low distortion, excellent mechanical properties in the weld zone, execution without a shielding gas, and suitability to weld all aluminium alloys [9]. Fixture is used to hold the sample plates which are welded by FSW process on the bed of CNC milling machine. Sample plates have to be clamped because these plates are to undergo high mechanical forces during the process. Special fixture is design as per requirements [10-11]. Literature review reveals that still there is lack of material property data regarding the comparison of FSW with TIG. Although it

is observed that FSW in general yields stronger welds than fusion welds more data is required to support this fact for time being few comparisons have been made of the dissimilar material welded by different methods with different process parameters.

II. INTRODUCTION TO ALUMINIUM ALLOY 5083

Aluminium is a chemical element in the boron group with symbol Al and atomic number 13. It is silvery white, and is not soluble in water under normal circumstances. Aluminium is the third most abundant element (after oxygen and silicon), and the most abundant metal, in the Earth's crust. It makes up about 8% by weight of the Earth's solid surface. Aluminium metal is so chemically reactive that native specimens are rare and limited to extreme reducing environments. Instead, it is found combined in over 250 different minerals. The main ore of aluminum is bauxite. Aluminium is remarkable for its low density and ability to resist corrosion due to the phenomenon of passivation. Structural components made from aluminum and its alloys are vital to the aerospace industry and are important in other areas of transportation and structural materials. The most useful compounds of aluminium, at least on a weight basis, are the oxides and sulphates. Aluminium 5083 is a high strength non-heat treatable alloy in commercial use. The major additive in the alloy is Magnesium. It has good formability and weldability and retains excellent tensile strength in the weld zone. It has excellent resistance to corrosion and high strength-to-weight ratio. The experimental material is selected as 5083 Al alloy sheets of 4 mm thickness, which is welded by Pulsed TIG welding and Friction Stir welds after surface preparation.

Table 1: Chemical Composition AA 5083

Element	Si	Fe	Cu	Mn	Mg	Zn	Cr	Ti	Al
% present	0.4	0.4	0.1	0.4-1.0	4.0-4.9	0.25	0.05-0.2	0.15	Remaining

The base metal employed is AA 5083 of chemical composition is shown in Table 1. Mechanical properties and Physical properties are shown in Table 2 and 3.

Table 2: Chemical Composition of Filler rod ER 5356

Ele	Si	Fe	Cu	Mn	M	Zn	Ti	Cr	Oth	Al
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% Pre sent	0. 2 5	0.4 0	0.1 0	0.05- 0.2	4.5 - 5.5	0.1 5	0.0 6- 0.2	0.0 5- 0.0 2	0.1 5	Ba lan ce

Table 3: composition of H13 Tool

Met al	Cr	Mo	Si	V	C	N i	Cu	Mn	P	S
Con tent (%)	4.75 - 5.50	1.10- 1.75	0.8 - 1.2	0.8 - 1.2	0.32 - 0.45	0 . 3	0.2 5	0.2- 0.5	0. 0 3	0.0 3

III. EXPERIMENTAL DETAILS

Pulsed tungsten inert gas welding machine was used to carry out the tig welding and for FSW a semi automatic universal milling machine was used. Different diameters of filler rods are used for tig welding I.e. 5356. The tool was mounted on the vertical spindle. Then two equipped aluminium pieces were clamped into the fixture. Then the rotating tool was made to insert into the butt joint. Then after some time, when there was adequate heating was achieved due to friction between tool and plates, the tool was given automatic feed, along the joint direction. Thus the welding was achieved. The schematic view of experimental setup is shown in Figure 1. After welding the pieces were cut into the samples of mandatory dimensions performing the micro hardness tests and SEM results.

IV. EXPERIMENTAL WORK

Pulsed current gas tungsten arc welding, developed in 1950's, is a variation of gas tungsten arc welding which involves cycling of the welding current from a high level to a low level at a selected regular frequency. The high level of peak current (I_p) is generally selected to give adequate penetration and bead contour, while the low level of background current (I_b) is set at a level sufficient to maintain a stable arc. This permits arc energy to be used efficiently to fuse a spot of controlled dimensions in a short time producing the weld as a series of over lapping nuggets and limits the wastage of heat by conduction into the adjacent parent material as in normal constant current welding, the fact that heat energy required to melt the base material is supplied only during peak current pulses for brief intervals of time allows the heat affected zone (HAZ). The technique has secured a niche for itself in specific applications such as in welding of root passes of tubes and in welding thin sheets, where precise control over penetration and heat input are required to avoid burn through.

For friction stir welding and tig welding same metal i.e AA 5083 sheets, 4 mm thickness for butt joint is used. For tig welding different diameters of electrodes are use and the material is 5356 i.e same composition as base metal. For tig welding a vertical semiautomatic milling machine was used. The tool used for this process was made of H13 steel 18mm diameter with the length of the pin is 3.7mm. Firstly material cut by shear machine as required dimensions of 100 x 100 x 4 mm are prepared and weld was made by joining two pieces. The process of welding is FSW completed by one pass by using H13 steel and weld samples of weld at different conditions by changing one parameters and keeping two parameter constant such that total number of samples are 27 from each welding.

Table 4. TIG welding process parameters

Specimen Id	Welding current(amps)	Gas flow rate(lt/min)	Filler rod dia.(mm)
7	180	12	1.6
15	210	10	3.2
27	240	12	3.2

Table 5. FSW Process parameter

Specimen Id	Tool rotational speed(rpm)	Welding speed(mm/min)	Angle of the Tool (degrees)
7	700	100	90
15	900	80	91
27	1100	100	91

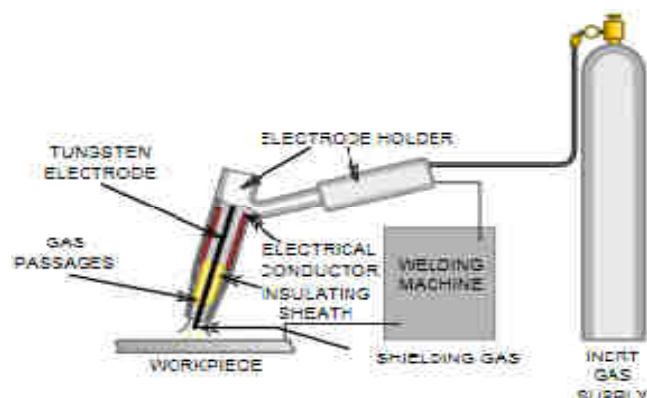


Fig.1: Schematic diagram of gas welding

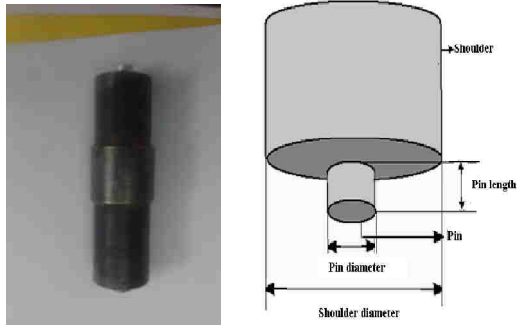


Fig.2: Friction stir welding Tool H13 and Tool geometry



Fig.3: Before welding clapping & Alignment



Fig. 4: Experimental setup



Fig. 5: Samples of TIG and FSW



Fig. 6: Samples by EDM

V. RESULT AND DISCUSSION

a. Micro hardness test

Table 6: Base Metal AA 5083

Base Metal	78.39
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Table 7: Average values of micro hardness

Sl.No.	Sample Id	Average Values	
		TIG	FSW
1	7	73	79
2	15	79	80
3	27	86	80

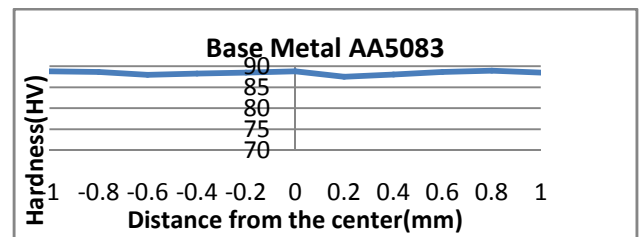


Fig. 7: Micro hardness curve for base metal

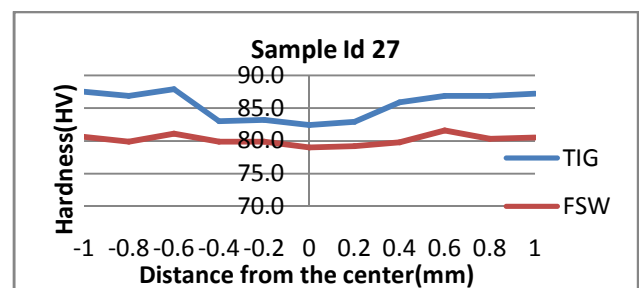
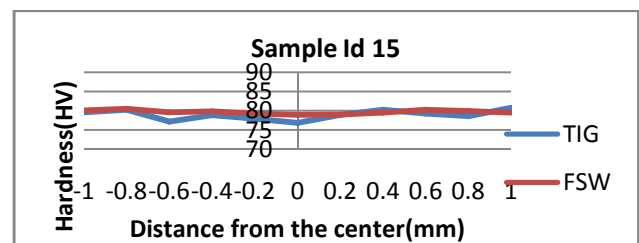
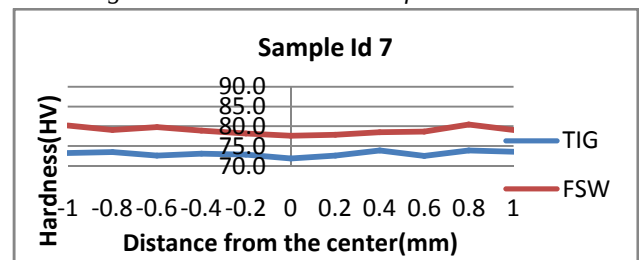


Fig. 8: Comparison Micro hardness curves for Tig and fsw

b. Sem photos

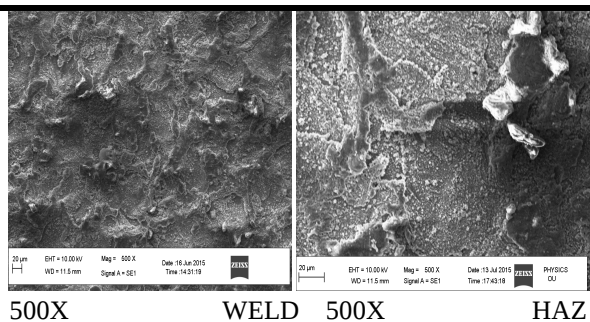


Fig.9: Tig Sample 7

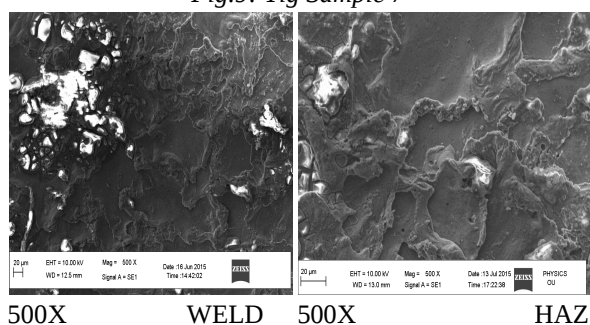


Fig.10: Fsw Sample 7

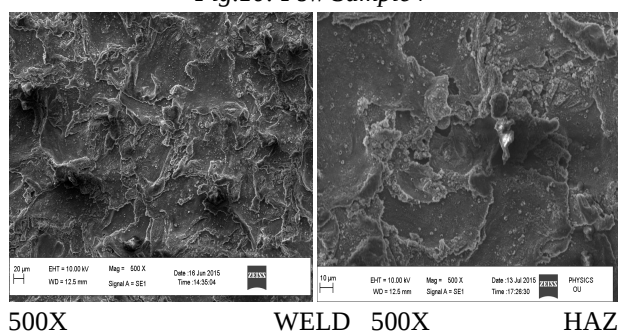


Fig.11: Tig Sample 15

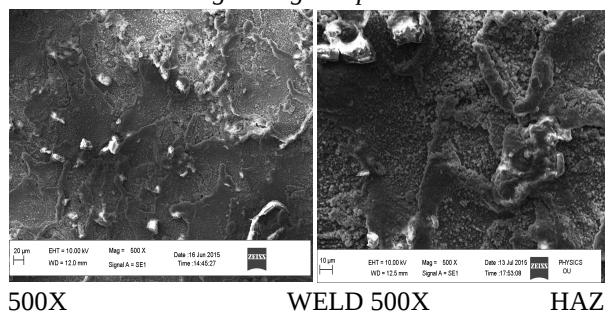


Fig.12: Fsw Sample 15

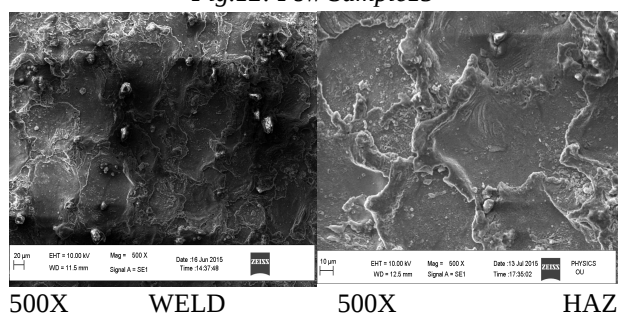


Fig.13: Tig Sample 27

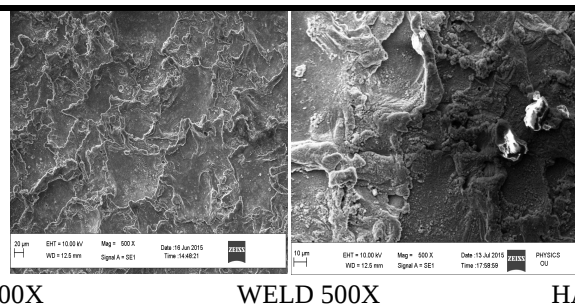


Fig.14: Fsw Sample 27

c. Chemical analysis test

Table 8: Sample 15

Sl.No	content	base metal specifications	TIG	FSW
1	Cu	0.10 MAX	0.01 MAX	0.094
2	Mg	4.0-4.9	3.63	4.41
3	Si	0.40 MAX	0.276	0.284
4	Fe	0.40 MAX	0.353	0.383
5	Mn	0.4-1.0	0.522	0.525
6	Zn	0.25 MAX	0.078	0.077
7	Ti	0.15 MAX	0.033	0.034
8	CR	0.05-0.25	0.114	0.115
9	Al	remainder	remainder	remainder

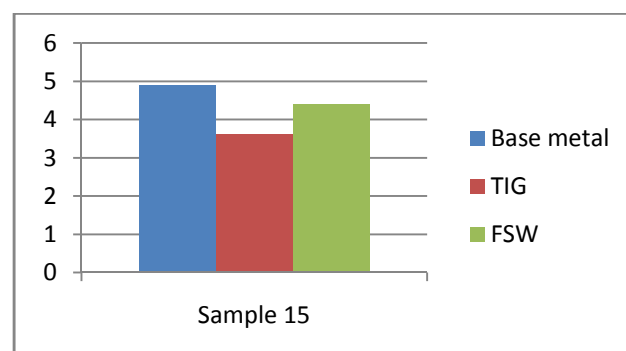
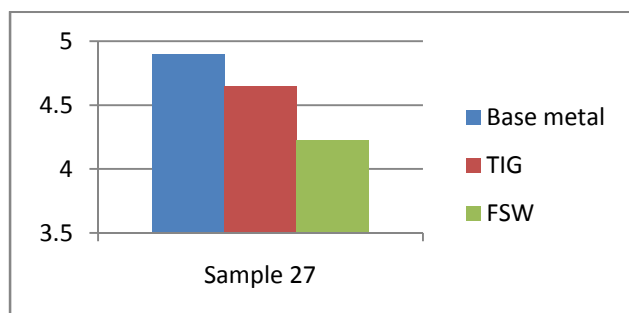


Table 8: Sample 27

Sl.No	content	base metal specifications	TIG	FSW
1	Cu	0.10 MAX	0.094	0.088
2	Mg	4.0-4.9	4.65	4.22
3	Si	0.40 MAX	0.292	0.283

4	Fe	0.40 MAX	0.368	0.353
5	Mn	0.4-1.0	0.547	0.528
6	Zn	0.25 MAX	0.079	0.075
7	Ti	0.15 MAX	0.035	0.033
8	CR	0.05-0.25	0.118	0.115
9	Al	remainder	remainder	remainder



VI. CONCLUSION

Using Vicker's hardness testing machine hardness across the welds cross-section was measured. Micro hardness measurements(HV) has been carried throughout the weld region for FSW and TIG welded similar metal aluminium alloy AA5083 to determine the hardness of different regions across the weld region. The middle section of weld region has been chosen for the hardness measurement. Base metal hardness value is 78.39. In FSW it is found that as tool rotating speed increases hardness also increases. From the all above graphs is found that for almost all the samples of microhardness values are increased for FSW than TIG weld joints. However friction stir weld specimens showed higher micro hardness as compared to shear stresses induced by tool motion which leads to generation of very fine grains structure which allows partial recovery of hardness. In TIG joints coarse dimples are seen and in FSW fine dimples are observed. So the fine dimples in FSW are the reason of higher strength properties as compared to TIG welded joints. Then from the chemical analysis test found that the percentage of magnesium is decreased in TIG weld joint and the slight decrement is seen in FSW joints. This is reason for in TIG Welding very high temperature increases and the cooling rate is very slow, so the magnesium is evaporated such that the strength of the TIG welded joint is decreased.

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